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ABSTRACT

The tenth paper of the Research Review Series, commissioned by the Science and Mathematics Education Information Analysis Center in cooperation with the National Association for Research in Science Teaching, provides an analysis of the documents released in 1971 which deal with science education research. The review is intended to: (1) provide a characterization of the current state-of-the-art and an examination of its key strengths and weaknesses as a guide for future research, (2) present a portrayal of the findings and conclusions of the research conducted in 1971, and (3) serve as a reference to studies conducted on a particular topic during 1971. Tables provide a categorization of the studies by topic, source, school level, and methodology employed. After outlining the reviewing procedure and general characteristics of the research, an analysis of the studies, illustrated by selected reports, is presented under the following headings: Instructional Procedures and Materials; Learning and Learner; Teaching and the Teacher; Methodological Studies; and Miscellaneous Topics. The bibliography contains 378 citations, mainly journal articles and unpublished doctoral dissertations. (JR)

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SCIENCE EDUCATION INFORMATION
REPORTS

RESEARCH REVIEW SERIES - SCIENCE
PAPER 10
REVIEW OF RESEARCH IN SCIENCE EDUCATION FOR THE YEAR 1971

By
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Boulder, Colorado

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ERIC Information Analysis Center
for Science, Mathematics, and Environmental Education
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April, 1973

SCIENCE, MATHEMATICS, AND ENVIRONMENTAL EDUCATION INFORMATION REPORTS

The Science, Mathematics, and Environmental Education Information Reports are being developed to disseminate information concerning documents analyzed at the ERIC Information Analysis Center for Science, Mathematics, and Environmental Education. The reports include four types of publications. Special Bibliographies are developed to announce availability of documents in selected interest areas. These bibliographies will list most significant documents that have been published in the interest area. Guides to Resource Literature for Science, Mathematics, and Environmental Education Teachers are bibliographies that identify references for the professional growth of teachers at all levels of science, mathematics, and environmental education. Research Reviews are issued to analyze and synthesize research related to science, mathematics, and environmental education over a period of several years. The Occasional Paper Series is designed to present research reviews and discussions related to specific educational topics.

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RESEARCH REVIEWS - SCIENCE

Research Reviews are being issued to analyze and synthesize research related to the teaching and learning of science completed during a one year period of time. These reviews are usually organized into three publications for each year according to school levels--elementary school science, secondary school science, and college science.

The publications are developed in cooperation with the National Association for Research in Science Teaching. Appointed NARST committees work with staff of the ERIC Center for Science, Mathematics, and Environmental Education to evaluate, review, analyze, and report research results. It is hoped that these reviews will provide research information for development personnel, ideas for future research, and an indication of trends in research in science education.

Your comments and suggestions for this series are invited.

Stanley L. Helgeson
and
Patricia E. Blosser
Editors

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A REVIEW OF RESEARCH IN SCIENCE EDUCATION FOR THE YEAR 1971

by

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THE REVIEWING PROCEDURE

Just as the researcher is obligated to carefully describe the procedures followed in his research, so the reviewer of research is obligated to describe what process he has employed in preparing his review. This review began with a search process conducted by the Science, Mathematics and Environmental Education ERIC Center to identify all documents released in 1971 which dealt with science education research. The documents obtained in this initial search were then screened by this reviewer to eliminate (2) non-science education studies, (b) duplicates of previous years' research which found their way into the initial collection of studies, and (c) other reviews of research.

The process of eliminating duplicates was necessary to cast out journal articles which were essentially duplicate reportings of the same study in another journal (at best, a highly questionable practice for a researcher) and to eliminate from this review studies which had been reviewed in a slightly different form in earlier ERIC sponsored reviews of a year's research (for example, a journal article based on an earlier dissertation and/or paper presented at a professional meeting). This review includes all unduplicated studies known to have been released in 1971 and a few studies from the previous two years which were not referenced in the ERIC reviews of those years. This screening process resulted in the 375 studies included in the 378 entry bibliography of this review. This process of screening of studies results in most dissertations being reported as such rather than as journal articles, and in non-dissertation studies being reported as journal articles or other reports.

In preparing this review, the reviewer read in their entirety all the studies which appeared as journal articles, read the dissertation abstracts for all research reported as a thesis (with an occasional reference to the actual dissertation) and in the case of papers presented at professional meetings and other research reports, read either an abstract of the study or the actual report. If properly written, the dissertation abstracts provided sufficient information to make initial judgments about the methodological adequacy of the study (particularly to rule out that large portion of studies which have serious methodological flaws). Of course, closer reading of the actual studies in the

case of those that pass this initial screening would rule out additional studies. In terms of making judgments about the significance of the conclusions of the studies (assuming methodological adequacy), the dissertation abstracts were generally complete enough.

Upon initial reading, all studies were rated in terms of (a) methodological adequacy and (b) significance of the findings and conclusions. Each study was also classified according to the topic of the study and the type of research methodology employed. On the basis of this initial reading and rating of methodological adequacy and significance of results, studies in each topic category were selected for review. Studies with obvious serious methodological flaws and apparently insignificant findings were referenced only and not specifically discussed. These criteria were not the sole basis for this dichotomizing of the studies, however, since the intent of this review is to characterize the 1971 research. Studies were sometimes included or excluded from the specific discussion in terms of their usefulness for this characterization or their value in illustrating a particular point. In other words, even though a study was chosen for discussion or reference largely upon its judged quality, this assignment cannot be taken as a completely accurate portrayal of quality because of the variation in the application of the criteria, the depth with which some of the studies were examined, and the lack of any reliability check on the ratings of the studies.

A brief comparison of the approach used herein and that used in another research review in which this writer participated [a review of the research on the training of educational research, development, diffusion and evaluation personnel by Worthen, Anderson, and Byers (371)], may serve to better identify this review's nature and serve as a basis for recommendations of the type of reviews that should be undertaken in the future. In the review of the research on training educational personnel, an extensive format for presenting a summary of a research report was prepared in accordance with a previously developed schema for rating the methodological adequacy of educational research studies. A team of reviewers then read the original documents and prepared extensive summaries of each study within this format. On the basis of these summaries, selected research methodologists from across the country then evaluated all the studies in accordance with a pre-prepared rating schema to eliminate all studies or portions of studies that did not meet tests of methodological adequacy. All studies were rated independently by two judges and in cases of discrepancies between these two judgments, the study was reviewed by a third judge. The majority of the research was eliminated from consideration on this basis. The remaining conclusions were then synthesized to present a comprehensive picture of what research had to say about the training of educational researchers, developers, diffusers, and evaluators. The current review differs from the above synthesis in at least two important regards. First, the thoroughness and extensiveness of the rating of methodological adequacy in the earlier review were of a different order of magnitude involving an entire project staff and the expenditure of considerable funds.

Second, a synthesis of findings was prepared, something that is not possible unless all of the research on a particular topic from over the years is examined together.

This discussion now brings us to the current review and what it is intended to accomplish. First, it is intended to provide a characterization of the current state-of-the-art and an examination of its key strengths and weaknesses as a guide for future research. Second, it is intended to provide a portrayal of the findings and conclusions of the research conducted in 1971. Third, this review should serve as a reference to studies conducted on a particular topic during the given year.

Although the current review should serve a useful purpose and a need exists for similar reviews to be conducted in future years, there also would appear to be a need for another type of review. This additional type of review would be similar in character to the Worthen, Andersen, and Byers review described above or in the tradition of the Review of Educational Research issues of recent years where the major research on a specific topic is screened, examined in depth, and synthesized to provide a composite picture of what research has to say on a particular topic. Such reviews are useful both for the user of research findings and as a guide to the researcher who wishes to direct his work into that particular topic. Hopefully, such reviews of selected science education topics will be promoted in the future and an outlet for their publication provided.

GENERAL CHARACTERISTICS OF THE RESEARCH

This section contains a brief description of the overall pattern of research conducted in 1971. When the 1971 research was categorized according to topic, Table I resulted. The body of this review is organized according to the same topics and in the same order; the categories will be defined more fully therein. Many of the studies contained within this review logically could have been included in two or more of the various topic categories used to classify the studies. A judgment was made, however, as to the one category in which a study most logically belonged on the basis of its key contribution. Thus, the reader is advised that when searching for studies related to a particular topic, he should examine studies included in closely related sections as well as the section that appears to be most germane to his interests.

TABLE I

CATEGORIZATION OF STUDIES

BY TOPIC

TOPIC	NUMBER OF STUDIES
Instructional Processes & Materials	
Development Reports	12
Evaluation	62
Instructional Procedures	103
Learning and the Learner	
Educational Outcomes and Related Factors	23
Learning Theory	17
Learner Characteristics	18
Teaching and the Teacher	
Teacher Characteristics and the Teaching Act	28
Teacher Education	44
Methodological Studies	22
Unclassified Studies	46
Total	375

In Table II, the studies are categorized according to their source. It is apparent that doctoral dissertations provide the bulk of the research done in science education. Because of the criteria used in selecting studies for this review as outlined above, this table provides a fairly good indication of the percentage of research done via dissertations. A study is not reviewed more than once in this annual reviewing process and appears as a dissertation rather than as a journal article.

TABLE II

SOURCE OF STUDIES

Dissertations	220
Journal Articles	112
Other Reports	43
Total	375

It would seem to be in order to present here the usual lament about the large percentage of science education research that is done via dissertations, but there probably is an even more significant viewpoint that could be added, i.e., that the quality of these dissertations could be substantially greater. One possible reason for this lack of quality may be that so little research is done by professors themselves that the student's mentor does not provide a model for research activity. The review of research on the training of educational research, development, diffusion and evaluation personnel referred to above indicates quite clearly that the apprenticeship relationship between the scholar and his student is the key identified means of producing productive researchers.

The school level of the studies reviewed is indicated in Table III.

TABLE III

SCHOOL LEVEL OF STUDIES

Elementary	86
Secondary	148
College	111
Combination	30
Total	375

It shows that the number of college studies is larger than the number conducted at the elementary school level (grades K-6). Further examination of the data indicates that over half of these college studies are studies of instructional procedures, such as comparing computer-assisted instruction with traditional instruction or comparing audio-tutorial instruction with a lecture-discussion approach. One gains the impression from examining the studies within this review that science education research at the college level is somewhat behind the research conducted at the other two levels in terms of quality and, over time, is evolving through somewhat the same pattern as research at the other two levels.

Table IV classifies the studies according to the research methodology employed.

TABLE IV

METHODOLOGY EMPLOYED

METHODOLOGY	NUMBER OF STUDIES
Experimental	151
Correlational	84
Survey	57
Evaluation	24
Methodological	22
Case Study	14
Development	12
Content Analysis	7
Historical	2
Philosophical	2
	375

It is encouraging to see that experimental studies far outnumber either correlational studies or surveys, two of the traditional methodologies employed in science education research. This comment is particularly

relevant for surveys since the great majority of them were judged in this review to be not particularly valuable in terms of contributions made to the literature.

There is a real place, of course, for well-done correlational studies and there probably is little reason to encourage a great decline in their numbers, in contrast to the situation with surveys. The quality of the correlational studies contained in this review is another matter, however, and there is considerable reason to encourage improvement in their quality. There is still room for additional methodological studies, particularly in the area of instrument development.

The category labeled "evaluation" deserves further comment. Since the mid-1960's there has been a rapid emergence of a new methodology, or possibly it could be more accurately portrayed as a new conceptual framework, for the evaluation of educational endeavors. Although many of the studies included in this category employed an experimental or correlational approach to part of the work undertaken, they were judged to be broader in scope than a single experiment and were basically evaluations of many characteristics of an educational product or process. In view of this fact and the apparent lack of broad understanding within the science education community of this emerging methodology or its implications, it appears particularly useful to identify such studies in a separate category as to methodology.

Studies labeled herein as development were primarily reports of development activities which lack a sufficient evaluation component to classify them as evaluation. This is a somewhat unfortunate category in that it would seem important to report to the science education community significant development activities, but without considerable evaluation work to report along with the story of the materials development, there seems to be little merit in presenting the report.

Although few in number (probably for good reason) the case studies included within this review seem to have an important dimension to add. Much the same comment could be made about studies that employ content analysis procedures. Probably the most disappointing categories in terms of their number are the historical and philosophical studies. Studies of this nature have much to contribute and quality endeavors in this area certainly should be strongly encouraged.

Some general comments about the research methodology employed in the 1971 research seem appropriate at this point. One is that the insights concerning internal validity of studies which were brought to the attention of the educational research community in the classic little work by Campbell and Stanley (45) in 1963 seem to have made a substantial impact on science education research. Unfortunately, it appears that their equally important insights concerning external validity of research studies have not been so widely understood. The extensive use of pretest-posttest designs when a posttest only design would be more

appropriate is but one indication of the current level of understanding. More basic is the evident lack of understanding of the total composite of considerations that bear upon the degree of generalizability of a study. Careful attention to the first 25 pages of that classic chapter along with careful thought about their implications for science education research would be particularly valuable for any researcher who has not yet given intensive and extensive consideration to the problem of external validity.

A second general comment about the methodology employed in science education research relates to the emerging methodology of evaluation referred to above. Careful consideration of such differences as those between formative and summative evaluation, between goal-directed evaluation and goal-free evaluation, and between evaluation of decision making and for decision making, have potential benefit for the researcher. For one thing, it might encourage researchers to redirect some projects from futile attempts to produce publishable generalizable studies to evaluation thrusts which, although not publishable, would have far more potential of benefiting the local educational endeavors which are under study. Secondly, careful study of the literature on evaluation methodology has the potential of providing many broadening perspectives and insights relative to research. For example, the concern of evaluators for careful description of what is being evaluated might well be examined with particular interest by persons conducting comparative experimental studies. One of the key problems with comparative studies conducted in science education is the lack of descriptive information indicating what actually has been compared. The evaluator may well have some important suggestions to offer here.

All in all, it appears that science education researchers could benefit greatly from closer examination of the literature on research methodology. In doing so, however, care must be taken to look beyond the questions of design and analysis to the question of what constitutes a research problem with the potential of contributing to the science education literature when its solution is attained. For most often, the most serious difficulty with a study is the insignificance of the problem addressed, regardless of whether the chosen design and analysis were appropriate or inappropriate. More specific comments on methodology will be made in the various topical sections below.

INSTRUCTIONAL PROCEDURES AND MATERIALS

Considerable attention has been directed to instructional procedures and materials. It is difficult to separate the study of procedures and materials since some processes and instructional procedures require particular materials and in turn, many materials are developed to be used with a particular instructional approach. A distinction which will prove useful for organizing this presentation, however, is that between research, development, and evaluation.

Research, which is the focus of attention of this review, is the enterprise directed toward the production of generalizable knowledge. The word "knowledge" serves to distinguish research from development in that the development process is directed toward the production of materials or procedures which have direct application in educational practice. The word "generalizable" serves to distinguish research from evaluation in that evaluation generally is focused upon a specific product or approach that is used within a given setting. The specificity and uniqueness of the situation in which the empirical data are collected, along with the fact that value judgments must be made in a true evaluation process, result in knowledge that is not generalizable to a very large extent.

Development and evaluation obviously are important activities which deserve a great deal of attention by science educators, but the results of such activities typically are not generalized information of the type that would be included in a review of research. There is a close tie between these three activities, however, in that the development of educational products and procedures should be based upon research, and the development process at its best includes extensive evaluation. An evaluation obviously depends upon many of the skills and techniques required in research, although this does not seem to be a sufficient basis for forgiving a fairly wide-spread lack of understanding among science educators of evaluation and the distinction between it and research.

Development

The search procedure used in collecting materials for this review yielded several reports of product-development activities. Although generally not producing extensive generalizable knowledge that should be summarized in this review, to make reference to them seems appropriate here for the benefit of the person who wishes to investigate such activities more thoroughly. A general comment that might be made about these reports is that, as with research, they vary greatly in quality. The development process is really not complete without careful evaluation of the product which results. Yet, even in some of the development activities reported as doctoral dissertations, where evaluation and careful evaluative study would seem to be favored, evaluation was essentially non-existant. This reviewer is of the persuasion that if the goal of a particular doctoral program is the training of the developer and/or evaluator rather than the researcher, that such activities are appropriate for the dissertation activity. There is little evidence among the development activities referenced herein, however, that the quality of such work presently done as doctoral theses really is worthy of the degree. Among the studies included in this review which are basically reports of the development activities are the following: (24), (55), (64), (93), (94), (129), (185), (195), (208), (343), (355), and (357).

Product Evaluation

A fairly extensive collection of evaluation studies has been reported, some being evaluations of products developed by the investigator but most being evaluations of curriculum materials developed by large-scale curriculum development projects. Overall this is not a particularly fruitful group of studies when compared to other categories of studies included in this review. The studies reported here generally focused upon summative evaluations, which is not surprising in view of the greater possibility of generalized knowledge being produced in this type of evaluation endeavor. It is unfortunate, however, that more of these evaluators have not chosen to expend a larger percentage of their energies on other aspects of evaluation. Formative evaluation of the product (i.e., continuous evaluation during development of the product and the process by which it is developed - not a limited summative evaluation, an activity for which the term has erroneously been used) as well as evaluation of the particular processes employed in operating a particular curricular program can serve a very important role in educational decision making.

Another characteristic of the evaluation studies contained herein is a lack of complete descriptive information. Thorough description is needed; what cannot be described cannot be evaluated. Simply naming the curriculum materials employed or describing very sketchily those materials whose title is not well known is not adequate as a basis for evaluation. Thorough descriptive information must be given which delineates clearly the essential differences between two sets of materials that are being compared or the essential characteristics of a single approach or collection of materials that is being evaluated. In many cases, this means conducting rather extensive data collection and empirical work to come up with the descriptive information needed as a basis for the evaluation.

In examining this group of studies, one also is confronted immediately with the general problems of comparative studies, i.e., comparison of two different sets of materials, such as a "modern" curricular package and a "traditional" program. These comparative studies generally establish whether or not one of the two approaches more adequately attains given ends under the particular circumstances where the study was conducted. But the intent is to attain generalizability and these studies usually give little hope of establishing much about the outcomes of the curricular materials involved within situations other than those of the given study. It is very difficult to determine the effect of the particular materials in the midst of all the other variables involved. For example, a well-done study reported by Milkent (219) yielded a fairly common result for studies of this type. "The teacher was a more important factor in contributing to student understanding....than was the use of the curriculum materials developed in this study." This finding is of importance but it leaves unanswered the questions about the relative merits of the materials being compared.

Examples of a few of the better studies in this group are described. Barrow (16) conducted a study to determine the extent of differences in "concept and principle learning about organic evolution" among tenth graders of average or above ability under two different methods of high school biology instruction (BSCS and traditional). Using randomly assigned students, a pretest-posttest control group design, and statistical procedures which included analysis of co-variance, he found no significant difference in "concept" achievement but a significant difference in "principles" achievement in favor of the BSCS group. DeOliva (81) studied the effectiveness of the BSCS single topic inquiry films with respect to increasing tenth graders' ability to recognize criteria for rejecting or accepting hypothesis and for evaluating experimental design of experiments. Basically, it was concluded that instruction with the films was no more effective than without the films for students of all ability groups and sexes.

A study was conducted by Baldwin (11) to investigate the effectiveness of a "process-oriented" curriculum for furthering higher thought processes among higher ability students. The nested design employing analysis of variance, random assignment of students and posttesting only is commendable. The findings of the study point toward the merits of a process-oriented curriculum for developing higher thought processes among high ability students. "The study also indicates that teaching methodology as well as curricular content must be considered in organizing curricula in terms of specialized outcomes for high potential students." Another study which can be described as methodologically adequate is a study of attitude change as a result of sex education conducted by Hoch (142). The particular materials being evaluated were employed within a high school biology course. Among the conclusions of the study were that an increase in factual knowledge resulted, permissiveness in attitude toward sexual behavior did not increase and students had a greater consciousness of problems such as population control, family planning, birth control, and abortion and tended to be "more liberal" with respect to these topics.

A study which is commendable both with respect to its methodological adequacy and its attempt to investigate more facets of the materials under study is one reported by Wideen (364). His study involved 26 teachers and 555 students, with the data being treated by analysis of variance and covariance. He concluded that Science - A Process Approach had a consistently better effect on process skills within the cognitive domain. He found this curriculum, however, to be no more effective in terms of increasing students' interests in science-related activities nor in bringing about a more positive perception of their classroom and teacher. In general, it was concluded that this curriculum contributed to a "fairly specific set of student outcomes" and that the teacher was also an important variable.

A study which succeeds somewhat in moving beyond the limitations which are common to most comparative studies is one conducted by Wasik (352) to compare PSSC and non-PSSC physics students. He attempted to

determine what cognitive abilities are emphasized within these curricula and how student achievement and aptitude are related within these curricular approaches. Using data from a random sample of students taking the College Entrance Examination Board's physics achievement test, he concluded that the non-PSSC group performed significantly better on the knowledge measure while the PSSC group performed significantly better on the analysis measure. He also concluded that the results of his study generally supported the contention that the PSSC materials were more effective for developing higher cognitive process skills.

A study was conducted by Adams (3) to determine if there was a consistency between the type of biological information contained in news articles and the content of the BSCS textbooks. Thus, the study employed a survey of the content of news materials and a content analysis of the BSCS materials followed by a comparison of the two. Adams found that there were many biology and biology-related news items found in the public press and there was a close relationship between these biological principles and those stressed in the BSCS textbooks.

In summary, it might be said that there is more room for improvement in the area of evaluation studies than in many other categories which are included within this review. Other evaluation studies include the following at the elementary level: (4), (10), (20), (60), (110), (136), (148), (167), (173), (179), (204), (224), (313), (317), (346), (353), (359), (365), (372), and (378).

The following studies pertain to evaluation at the secondary level: (32), (33), (58), (69), (82), (124), (163), (168), (172), (200), (201), (212), (227), (247), (262), (269), (275), (292), (302), (304), (308), (315), (329), and (366).

At the college level, the following studies pertain to evaluation: (74), (83), (99), (118), (122), (157), (230), (234), (306), and (321).

Instructional Procedures

This section contains studies which, in many respects, are very similar to those in the previous section. In many cases the researcher is comparing two different instructional procedures in a manner analogous to the comparative studies discussed above. Under product evaluation, the investigator typically attempted to evaluate a particular course or set of instructional materials that had been developed. In this section the focus is more directly upon a particular instructional approach such as instruction by an auto-tutorial procedure or computer-assisted instruction. In the previous section, the investigator generally was attempting to evaluate a particular product while the studies reported in this section generally are an attempt to make a more general statement about a particular instructional approach. Obviously the two sections overlap greatly and the determination as to which section a particular study should be reported in may depend upon the language used by the investigator in reporting his work.

In describing the research done in this section, the studies will be broken down into three categories according to instructional level - elementary, secondary and college.

Elementary. The fewest number of studies of instructional procedures and processes was found at the elementary level. A study was conducted by Tucker (341) to examine the influence of "process-oriented television science" on several factors including student process and concept achievement, teacher process and concept achievement, and teacher process questioning. The study employed random assignment of volunteer teachers to one of four combinations of televised elementary science instruction and/or regular science instruction. Pre- and posttest data were collected via written instruments and audiotape recordings of teacher's questioning behavior. No significant differences were found in pupil and teacher achievement gains but significant differences in favor of the TV teachers were found on Test On Understanding Science (TOUS) scores. The analysis also indicated that the "non-TV" teacher used a higher portion of recall questions than those teachers using the process-oriented television science. Other aspects of the study led the author to conclude that the study demonstrated "the importance of the conceptual and contextual nature of instructional materials" as an influence on the type of questions which teachers ask.

In a well designed study, Siegel and Raven (298) investigated the effects of children's manipulative experience on their acquisition of compensatory concepts of speed, force, and work. The subjects consisted of 120 fourth grade children randomly assigned to three groups - a manipulation group, a demonstration group, and a control group. The study was based on Piaget's theory of psychological development and in general concluded that "it is possible to increase stabilization of the compensation scheme at the developmental level through the use of manipulation or demonstration techniques."

In another well designed study, Raven and Strubing (263) attempted to determine if learning of second grade children using one of the SCIS units could be improved through prior training with materials designed to develop visual perception. They concluded that the particular type of perceptual training provided in their study was not the most significant factor in influencing achievement on the unit Relativity Of Position and Motion.

Other studies in this section are the following: (1), (23), (50), (76), (92), (194), (260), (295), (297), (340), and (344).

Secondary. This collection of mainly comparative studies includes investigation of a considerable variety of different instructional procedures. A study by Egelston (90), which compared inductive and traditional methods of teaching high school biology laboratories appears at first glance to be just another one of many such studies. It goes beyond the typical study, however, in that in addition to being well designed, it includes considerable descriptive information which makes

it possible to tell what approaches really are being compared and because it goes beyond simple comparison on the basis of cognitive achievement. Classroom behavior was categorized with an observation system and used as a basis for determining what instructional approaches really were being compared. The conclusions of the study dealt with specific kinds of instructional procedures that can be expected to result in particular types of outcomes.

Although designed better than the average study in this section, an investigation by Simmons and others (300) suffers by comparison with the Egelston study. No attempt was made to measure any outcome other than cognitive achievement via the BSCS Biology Achievement Test nor was any attempt made to explain individual variations in terms of the methods employed. Random assignment of subjects and analysis of co-variance were used in this comparison of (a) a conventional teacher-direct class, (b) a combination of teacher-directed methods and independent study, and (c) independent study methods only. Approaches (a) and (b) were not found to be significantly different from each other but both resulted in better group achievement than did (c).

Summerlin (325) conducted a study to determine the comparative effectiveness of "short-term, tutorial type, computer-assisted instruction" in selected high school chemistry topics. Random assignment of students within a posttest only design was employed. Students in the control group performed better on both an initial posttest and a second posttest given 60 days later.

In another chemistry study, Anderson (8) dealt with a comparison of an individualized instructional method which incorporated programmed study with other types of experiences and a control group which had lecture, laboratory and film-viewing experiences in common with the experimental group. A randomized posttest design and an analysis of co-variance were employed to compare cognitive achievement. No significant differences were found for method. IQ and previously acquired mathematical skills were influential factors but no interactions were found to be significant.

Within the context of a programmed course in basic electricity, Stiegler (319) compared the effects of explanatory feedback and non-explanatory feedback upon student achievement. A pretest-posttest design incorporating a 2 x 3 (ability level x feedback form) factorial analysis was employed. Differences between these two particular forms of feedback were found to be not significant.

Another well designed study is particularly interesting because it is on a general topic which has given promise of being a useful instructional tool but which is not being investigated very extensively in science education. Liao (190) studied the use of a simulation technique for learning modeling concepts and skills. An analog computer was used in this simulation study which resulted in significant results in favor of the simulation techniques. A wide variety of simulation techniques (not simply computer-based ones) have been investigated rather extensively

in some other fields, and they deserve greater attention on the part of science education investigators.

Still another instructional procedure was investigated in a study by Schiller (284) in which a comparison was made of the effectiveness of secondary school biology laboratory teams organized either sociometrically or randomly. Among the effectiveness criteria included were attitude toward science, laboratory efficiency, compatibility, and understanding of science processes. Based on this pretest-posttest study employing analysis of co-variance, the investigator concluded that sociometrically organized laboratory teams were better than randomly organized teams.

In one of the very few studies in this section which rival the Egelston study cited above in terms of description of the teaching approaches compared and completeness of the outcomes investigated, Johns (158) compared the relative effectiveness of a conventional method of teaching general science and a "discrepant events method." Instructional profiles were determined via a daily questionnaire and outcomes were compared in terms of critical thinking ability, cognitive learning, and retention of subject matter. Some differences were found in terms of cognitive learning but no significant differences were found in the retention of subject matter nor in critical thinking ability between experimental and control classes. The experimental treatment was found to result in superior achievement in the learning of concepts while maintaining equal level of achievement in operations and facts.

Schuck (287) conducted a study to investigate the effect of specifically training teachers to employ set induction techniques in their instructional strategies. Student achievement, student retention and teacher achievement were studied within a pretest-posttest design employing analysis of variance. Significant differences were found in favor of set induction in terms of both pupil achievement and retention while no significant differences were found in knowledge of the subject area on the part of teachers. The subject matter employed in this study was the biological topics of respiration and circulation.

In yet another type of study, Trindade-Khristanand (339) investigated the influence of serial order of the teacher-communicated content in science teaching. This was studied in terms of the acquisition of verbal knowledge. The investigator employed analysis of co-variance and concluded that "subjects receiving low-structured (random), intermediate-structured (static), and high-structured (high kinetic) science communications showed significant differences in acquisition of information, both with respect to descriptive and factual knowledge....and with respect to knowledge of the order in which component parts of a physical system can be organized."

The other studies at the secondary level were the following: (14), (15), (29), (38), (51), (63), (87), (101), (131), (144), (147), (156), (193), (272), (288), (299), (333), (358), (361), (368), (374), and (376).

College Level. In addition to being one of the largest contained in this review, this group of investigations is characterized by a preponderance of comparative studies in which two instructional approaches were the basis of the treatment variable. As such, this group reflects the general weaknesses attributed to comparative studies in an earlier section of this review and contains even less evidence than previous sections of attempts to overcome the most obvious of these weaknesses.

One of the weaknesses particularly disappointing to note is the lack of descriptive information, including empirical observation of actual classroom occurrences, that enable the reader to determine what actually is being compared. The possible lack of correspondence between what is described as the rationale of a given instructional approach and actual classroom occurrences is a matter of major concern. It is the obligation of a researcher to provide this information. Without it, the study has little potential for contributing to the science education literature, or more broadly, the total education literature.

A very important characteristic of educational research (and in fact, social science research, in general) is that a given study rarely has the possibility of being externally valid in the broadest sense of the term. That is, there is little possibility of generalizing beyond the specific school or school system in which the study is conducted. As a result, broader generalizations in educational research generally are acquired by examining a relatively large number of studies which have been conducted under fairly similar circumstances in a wide variety of schools, school systems and regions of the country.

Such synthesis of the results of a large number of studies, however, is impossible unless the researcher has provided descriptive empirical evidence of the actual educational procedures or approaches that were being compared. This reviewer is inclined to question whether or not a professor ethically can allow a doctoral student to conduct a dissertation study with a weakness as serious as this lack of descriptive information in view of the fact that this needed characteristic of comparative studies has been recognized for so long.

The second weakness of comparative studies which is particularly evident in this section was a frequent failure to study in depth variables other than cognitive achievement at the lower levels of Bloom's Taxonomy. Again, this weakness has been identified previously in this review but is particularly apparent in this section. The apparent extensiveness of these two weaknesses in this section may reflect the fact that empirical study of the educational process has more recently come to the attention of more of the people involved in college teaching. As a group, the studies within this section which are singled out for specific discussion below tend to be fairly meritorious in terms of internal validity. In almost all cases, however, there is concern about their external validity and this should be borne in mind when referring to them.

Young (375) compared a "team-learning approach" of teaching college physical science with a lecture approach. The team-learning approach involved students in the group solution of problems through group interaction. Twelve intact sections of a physical science class were randomly assigned one of the two methods, and analysis of co-variance was employed. Each of three instructors taught two sections of the experimental class and two of the control class. The author concluded that in terms of student achievement, the two methods did not differ significantly but there was a significant instructor effect. No instructor-method interaction was found. On a retention test, however, a method effect was found in favor of the control group. A final conclusion of this study illustrates the general problem found within this category of studies as referred to above. "Any attempt to explain the superiority of the control group in terms of an instructor effect must of necessity be based upon indirect evidence, since no formal attempt was made to observe the instructors in the classroom situation."

A lecture-discussion approach to teaching college physics was compared with a multi-media program method by Weiss (354). A significant method effect was found in favor of the multi-media program method but no teacher effect or interaction of teacher and method was found. In a comparison of an independent study method and a lecture method of teaching general studies biology, Stavick (316) employed the Nelson Biology Test and the Test On Understanding Science (TOUS) as measures of the dependent variables. No main effect difference between the two treatments was found although some significant differences were found with respect to several other independent variables which were considered.

Follette (98) compared an "intrinsically motivated" approach to teaching college earth science with a traditional lecture-discussion approach. Within the intrinsically motivated approach, the students were allowed to establish their own instructional goals and determine the means by which they would achieve them. The two approaches were compared both in terms of cognitive achievement and student attitude. The researcher found no significant difference in terms of student attitude toward science but found a higher level of cognitive achievement in the lecture-discussion group. He also concluded that most students will prefer the intrinsically motivated approach when given the opportunity to choose and that this approach is feasible in terms of instructor time.

Several studies were conducted in which alternative approaches to use of the laboratory at the college level were compared. Among these were the study by Crawford and Backhus (70) in which a "highly structured scheduled lab, an audio-tutorial type free lab, and a loosely structured home lab" were compared on the basis of the TOUS and a measure of cognitive knowledge. No significant differences were found in this study of college physical science in terms of cognitive achievement and no significant difference was found on the TOUS during the first phase of this study, but during a second phase of the study significant differences were found on the TOUS in favor of the free lab and the home lab.

In a comparison of a conventional laboratory method with an "extended laboratory problem" approach in a college biology laboratory study, Smith (301) used an achievement test, the Purdue Attitude Test, and the TOUS as measures of dependent variables. Employing a 3 x 2 teacher by method design and analysis of co-variance, he found no significant differences and no interaction effects.

Reis (265) compared a physical science laboratory program "centered around a continuing experiment where the students themselves attempted to function as a team of scientists" with a second laboratory program which was "a direct examination of scientists and their work by having their students read, analyze, and criticize actual reports of contemporary scientific work and by having them visit and participate in discussion sessions with practicing scientists." In the first instance the students spent a large portion of their time involved in the several facets of scientific investigation while in the second instance, little actual work with equipment was involved. Instruments were developed to assess difference in five areas: (a) "Recognition and Formulation of Scientific Hypotheses," (b) "Testing of Hypotheses-Interrelationships of Hypothesis and Experiment," (c) "Testing of Hypotheses-Experimental Design," (d)"Testing of Hypotheses-Analysis and Interpretation," and (e) "Attitudes of Scientists Concerning Their Work." In terms of these five measures, no significant treatment or interaction effects were found. Other aspects of the two programs were studied and differences reported.

At the college level there appears to be considerable interest in programmed instruction, computer-assisted instruction, and other forms of highly structured instructional approaches. Sharon (293) compared two different "review techniques" as supplements to a basic course in college chemistry. A branched programmed text was compared to a standard type of manual as a supplement to the basic activities of the course. Initial differences were found in favor of the programmed instruction group but were not found on a retention test administered at a later date.

Culp and Lagowski (72) reported three related studies of computer techniques used in undergraduate organic chemistry. In general, results were found in favor of the computer-assisted instruction group over control groups when used as a means of supplemental assistance for students. Student attitude toward the computer-assisted instruction was reported to be favorable. In another study, Culp and Castleberry (73) compared the computer-assisted instruction supplemental activity in undergraduate organic chemistry with a non-computer assisted instruction supplement and a control group. Significant differences were found in favor of the computer-assisted instruction group over the other two.

In a study which suffers from inadequate reporting of the statistical analysis, Hollen and others (146) compared instruction in qualitative analysis by a simulated computer approach and by a traditional laboratory approach. No significant differences were found in achievement but the computer simulated group required significantly less time to complete their work.

Bessler and Nisbet (28) investigated the use of an electronic student response system within the context of teaching college biology. The system was used with a group-paced one year program and compared with control students in discussion sessions utilizing conventional discussion techniques. The authors employed analysis of co-variance and concluded that the two treatments were equally effective.

Audio-tutorial instruction in biology has received considerable attention from persons conducting empirical studies of college science teaching. Hoffman and Druger (143) compared a "direct" and an "indirect" style of audio-tutorial instruction. A particularly noteworthy aspect of this study was an analysis of the teaching strategies employed within these two categories. An analysis instrument described as being similar to the Flanders System of Classroom Interaction Analysis was employed. This study is one of the rare ones where descriptive information is provided that enables one to determine to some extent what really is being compared. No significant differences were found between the two groups in terms of critical thinking ability, cognitive achievement, or retention. There was a significant difference, however, in favor of the indirect group in terms of problem solving abilities. No significant attitudinal differences between the two groups were found.

In another study of audio-tutorial instruction in college biology, Sherrill and Druger (296) investigated the relationships among student variables on the basis of attitude, personality, and achievement data. Using a correlational approach, the authors concluded that neither achievement nor attitude were related to the personality dimensions they measured. Aptitude scores were found to be related to achievement but were unrelated to attitude.

In another audio-tutorial study, Kahle (165) compared a group receiving an advance organizer with a group which did not. Analysis of variance was employed and no significant difference found. A second aspect of the study was a correlational study of the effects of micro-learning tasks.

Brott (41) compared the effect of exposure to test questions of two different types throughout a semester. No significant differences were found between the two groups in terms of the student's ability to respond to either type of question.

Gatta (108) studied the effect of a pass-fail grading system on attitudes toward chemistry and achievement in college chemistry. He concluded that students who are generally of a high achievement level performed at a significantly lower level under the pass-fail system while no significant differences were found between the two groups for students from the middle level of achievement and for those from the lower level of achievement.

In addition to the above areas where several studies generally were reported on a given topic, there were a variety of studies reported which are one of a kind or at least rather isolated among the studies conducted

during the period under review. For example, Read (264) investigated the order of presentation of two topics in college physics. Studying a unit on wave motion before studying an optics unit was compared with the reverse order of presentation in view of hypothesized potential benefits of studying wave motions prior to optics. No significant differences were found on achievement tests or tests of retention given three months later.

Schrader (286) reported a study of the effect of the timing of informational presentations upon the cognitive synthesis process. The results of this study were said to support Ausubel's theory related to processing of information during storage and, as such, the study is closely related to others reported in a section below. Another study which is closely related to a later section is one by Kuhn and Novak (182). In this study of advance organizers within college biology, the use of the organizer principle was studied in two different ways. The authors give cautious support to the effective use of advance organizers.

Other studies within this section are: (2), (12), (49), (117), (121), (123), (128), (134), (135), (137), (145), (150), (161), (189), (205), (206), (207), (210), (223), (225), (226), (229), (239), (243), (248), (259), (280), (282), (303), (305), (310), (311), (323), (326), (335), (347), and (362).

LEARNING AND THE LEARNER

While the previous section of this review was focused upon the instructional procedures and materials employed in the educational process, this section shifts to the learner and what he learns. These studies are further subdivided into three categories: (a) studies of educational outcomes and factors which are related to these outcomes, (b) studies of learning theory, and (c) studies of student characteristics.

Educational Outcomes and Related Factors

The studies included within this section are almost exclusively correlational studies in which attempts were made to find relationships between certain outcomes (cognitive, affective and psycho-motor) and a variety of other variables. As a group they do not seem to represent a particularly large step forward in that there seems to be substantial rediscovery of significant relationships between the standard predictors of educational achievement such as IQ scores and science achievement.

One such study was conducted at the first grade level by Poole (254) in an attempt to ascertain the relationship between first grade science achievement and a large number of variables such as institutional variables, instructional variables, teacher's judgments of student's socio-personal adjustment and academic ability, biographical characteristics of students, and test scores. Stepwise linear multiple regression yielded

several predictors of science achievement at the first grade level. Two mental ability scores were the most important variables in the prediction of science achievement. A pretest science score was the next most important predictor and an instructional variable somewhat unique to the student population studied was a possible source of some of the variance. Additional variance in the prediction of the achievement was related to the student's likelihood of social success and self-image as estimated by teachers.

Hinerman (140) used regression analysis to study the relationships between scores on the Wisconsin Inventory of Science Processes (WISP), the Sequential Test of Educational Progress (STEP), and a variety of school and student characteristics. Significant positive correlations were found between STEP and WISP scores and the following characteristics: (a) semesters of mathematics completed, (b) semesters of science completed, (c) high school science grades, (d) high school mathematics grades, (e) percentage of the school's seniors going to college, and (f) the school's enrollment in grades 10-12. The correlation between WISP scores and STEP scores was found to be .48. The factors investigated accounted for 35.5% of the STEP scores variance and 21.8% of the WISP scores variance. Several student attributes such as critical thinking ability and abstract reasoning ability as well as most teacher attributes were not included in the investigation.

Alvord (5) investigated possible relationships between science achievement and student's attitude toward school and self concept. Low but significant positive relationships were found between science achievement and both self concept and attitude toward school generally. The significant relationships found between science achievement and attitude toward school vary according to race, sex, and other student characteristics.

Davidoff and others (77) undertook a study to ascertain the degree of relationship between achievement in a computer assisted instruction biology program and selected personality factors. An instrument called the Junior-Senior High School Personality Questionnaire containing 140 items designed to measure fourteen personality traits was employed along with two dependent variables: (a) score on a mid-year achievement test in biology, and (b) the total number of units of study completed within 60 days following that examination. The authors concluded that "when considered in combination, the personality traits as measured by the HSPQ were not found to be significant correlates of pupil performance." "The data from the present study did not support the idea of a relationship between achievement and personality in CAI biology. A competing hypothesis may be that the reliability of personality measures is so low that any relationship between personality and a criterion will be attenuated." The problems raised by lack of a comparison group in this study must be considered.

Several of the reports and the newsletters of the National Assessment of Educational Progress [Goodwin (115), Myers (232), Tukey (342)] are particularly relevant to science education. Summaries of the results

of these tests which were given to students age 9, 13, and 17 and adults in the 26-35 age group are available along with specific item by item responses to exercises. Results are broken down according to race, sex, age, region of the country, size of the community and other characteristics. One of the particularly important aspects of this major project is the longitudinal nature of their work. Thus, future cycles of this project have even greater potential of providing meaningful information.

In a college level study, Szabo and Feldhusen (328) employed multiple regression analysis to investigate selected learner characteristics as predictors of academic success within two different instructional systems. The independent variables were scores on the Guilford-Zimmerman Temperament Survey, high school grades and rank, College Entrance Examination Board and Scholastic Aptitude Test scores and biographical information. Because the two instructional groups had different subject matter and different instructors, making comparisons between these two groups is hard to defend but the authors are relatively cautious in making these comparisons. One result of their study which may bear further consideration is the apparent value of the restraint scale of the Guilford-Zimmerman Temperament Survey as an indicator of academic achievement within varied instructional approaches.

Another college level study was conducted by Tolman (338) to study differences between performance in biology programs of students in community colleges and those in four year institutions in Oregon. The results of this correlational study indicate that the level of success on three or four subtests of a test of principles of biology was not significantly different for the two types of institutions, with the community college students attaining a higher level of success on the knowledge subtest. Among the other findings of the study was that the biology students in the four year institutions attained higher scores on the Cornell Critical Thinking Test than did the community college biology students.

In a study which is of interest more because of the techniques employed than because of the conclusions, Riban (268) analyzed the mathematical deficiencies in physics problems into hierarchies of needed mathematical skills. Deficiencies were inferred from student performance on the physics problems and remediation was prescribed for individuals in experimental groups.

Other studies relevant to this section are the following: (30), (39), (96), (97), (114), (199), (202), (276), (320), (330), (348), (356), and (369).

Learning Theory

This section deals with learning theory and psychological constructs directly related to such learning. Although a few of the studies in this section can be regarded as experimental, the majority are correlational studies, as in the previous section. The type of studies contained in this section are often billed as the type that have great potential for

furthering our knowledge of science education. Such a view is based on the assumption that a meaningful theoretical structure for teaching and human learning in the area of science can be formulated which will serve as a sound basis for instruction and curriculum development. Although the extent to which this assumption actually holds is still open to question, studies of this type nevertheless carry a certain fascination as well as provide a stimulus for many researchers' optimism about the possibility of a science of education.

Included within this section are several studies which deal with Piaget's psychology of intellectual development. Parvand (246) conducted a study of the influence of practice of selected operations on the acquisition of conservation of substance and weight. He found practice to make a significant difference in the number of subjects who could be described as "conserving."

Phillips (252) conducted a study to determine the possible existance of a "sequential set of conservation concepts which lead to the conservation of displacement volume." The subjects included 120 children selected from three different grades (3rd, 5th and 7th grades) and having an IQ between 100 and 120. The tasks used in the study were based on selected levels of a proposed hierarchical model of the attainment of concepts which lead to conservation of displacement volume. Of the six levels tested, five were found to scale in the anticipated order. No significant difference was found between two methods of task presentation which were employed.

In a somewhat different type of study, of interest because of the methodology employed as well as the findings of the study, Thomson (334) empirically explored the use of computer simulated experiments as a means of diagnosing "elements of propositional thinking in the cognitive functioning" of students in the sixth and seventh grade level. A diagnostic instrument was developed which used computer simulated experiments. A determination was made of the effects of academic achievement, sex, intelligence, age, grade level, reading ability, and Piagetian tasks upon propositional thinking by employing the method of path analysis. Developed by sociologists and introduced to the science education literature by White (360) in 1969, this method of analysis permits the investigator to look at a large number of variables and build models which provide hypothesized cause and effect explanations of a complex collection of correlational data. In this study two models were developed and used to locate significant paths among the tested variables. This method of analysis deserves considerably greater attention than it has received thus far.

Berzofsky (27) conducted a study to explore three of the cognitive style dimensions displayed by third, sixth, and ninth grade students during their viewing, categorizing, and organizing of biological phenomenon. A picture-interview technique was employed which included pictures chosen to represent biological phenomena at five organizational levels - cell, organ, individual, species, and ecosystem. A stratified random sample

was employed with a 3 x 2 x 3 factorial design (grade level by sex by IQ level). The cognitive style dimensions investigated were (a) "perception, the selection of a part or the whole picture for matching," (b) "explanation, conceptual categories of biological structure, function, or history," and (c) "classification, the biological level of organization." Several patterns of relationships were found and reported in the study.

In a study of the relationship between cognitive structure and content structure, Shavelson (294) attempted to ascertain the degree of correspondence between the structure of instructional materials and certain aspects of a learner's memory structure. "Content structure was defined as the web of facts and their relationships in the instructional material. Cognitive structure was defined as a hypothetical construct referring to the organization (relationships) of concepts in long-term memory." The author concluded that as instruction progressed, the content structure and the subject's memory structure corresponded more closely.

In another study of cognitive structure, Ring and Novak (274) investigated the effects on college chemistry achievement of some dimensions of cognitive structure. They attempted to analyze the cognitive structure which beginning college chemistry students possessed prior to instruction and relate this to subsequent achievement. Seven hundred and seventy first-year college chemistry students comprised the sample. A test to ascertain cognitive structure was administered at the beginning of the course and regular periodic course tests were also used as sources of data. Additional information was acquired from student records and a questionnaire and used as covariants and for identification purposes. Among their findings were that "course achievement varied in a linear relation to the number of relevant subsuming concepts in cognitive structure" and that "students who possessed a large amount of facts without subsumers achieved at a very low level," and "very high achievement was a characteristic of students who possessed a cognitive structure in which facts were discriminable from subsumers." They concluded that the data in their study showed that "relevant cognitive structure, rather than general ability traits, is the determinant of learning success in chemistry."

Another interesting correlational study was built upon a proposed model of the learned relationships among physics concepts. Johnson and others (159) obtained data from physics graduate students that were found to be consistent with their model. The psychological relations of association and similarity which they investigated were discussed in terms of their role in evaluating conceptual knowledge.

Cohen (61) set out to determine whether hierarchically structured problem situations could be developed for identifying where an individual's solutions to physics problems were interrupted, and whether the approach employed by students in problem situations could be analyzed to yield information or constructs useful in college physics teaching.

Typescripts were obtained from tape recording of students engaged in problem solving. These typescripts were analyzed and the frequencies of the various behavior classifications used in the analysis. Results were reported in three categories: (a) cognitive, (b) affective, and (c) persistence. Among the affective findings reported were that successful solving of problems was related to degree of like or dislike for science courses, that the student's attitude toward course was related to his view of the teacher and the degree of success in solving problems was related to the anxiety experienced by the subjects while taking examinations.

The other studies contained in this section are (25), (37), (107), (119), (141), (188), (216), (233), and (377).

Learner Characteristics

A considerable number of studies have been conducted to ascertain the characteristics of science students and to some extent the relationships among these characteristics. The studies bear some resemblance to those in the section on educational outcomes and related factors but differ from those in that section in that the studies contained herein do not deal with educational outcomes directly. The studies contained in this section can be described as either surveys which simply produce descriptive information about a given group of students or as studies of a correlational nature in which the descriptive information collected is examined for the degree of correlation between the several variables under study.

Taken as a group, these studies are of the poorest quality of any of the categories of studies contained in this review. They tend to suffer from several defects. A common defect of crucial importance is a lack of specific hypotheses being tested or other conceptual guides that provide specific questions to be answered. Too often studies of this nature seem to be merely a random collection of data about a group of people who happened to be at hand. Without the needed conceptual underpinning, even great research methodology will still result in insignificant results.

A second problem is a lack of external validity. For descriptive information of this nature to be useful, it must be generalizable to some identifiable group in which other people might be interested. Too often it appears that people conducting these types of studies do them with some chance group of people, such as the students in a special program with which they are working. Under such circumstances, there is no hope of any real generalizability.

In summary, almost all of these studies lack one or more of the following three characteristics which should exist if the study is to be of any significance: (a) a conceptual framework which identifies hypotheses to be tested or questions to be answered, (b) a sample which has the potential of being a basis for generalizing to a larger and clearly

identified population, and (c) a correlational analysis of the information obtained to identify relationships between variables. (The inclusion of outcome variables seems particularly important if the findings are to be useful in science teaching).

None of the studies contained in this section can be pointed to as a model of what should be done. Although better than most of the studies in this section, a study by Koelsche and Newberry (178) of the science interest of children suffers from the generalizability problem referred to above and a lack of comprehensive identification of variables which might be related to science interests.

Other studies included in this section are the following: (47), (57), (88), (91), (95), (109), (153), (155), (174), (183), (196), (215), (253), (270), (327), (336), and (367).

TEACHING AND THE TEACHER

In this section attention is shifted to the teacher and the activities in which such a person engages. The studies are divided into two groups, the first of which deals with studies of teacher characteristics and the teaching process and a second section which deals with teacher education.

Teacher Characteristics and the Teaching Process

The studies contained within this section have many of the same weaknesses ascribed to the learner characteristics studies in the previous section, i.e., most of them suffer from a lack of one or more of the following defects: (a) lack of a sound conceptual basis in the form of hypotheses to be tested or questions to be answered, (b) lack of generalizability, and (c) failure to deal with other categories of variables which might be related to the teacher variables specifically under study. Although the first of these defects is a problem in this section, it is not as frequently a problem as in the above section.

There is a considerably large number of studies referenced below which suffer from defect (b), but are quite sound in terms of (c) and vice versa. The lack of generalizability is frequently a problem with these studies because the researcher focused upon a rather specific group of teachers of a particular type. For example, a researcher may study the participants in an NSF Inservice Institute who are studying a particular curriculum project. In other cases, a study may be focused upon the teachers within a given school district who are using a particular set of curriculum materials. That such a group of persons is unique in many ways should be quite obvious.

This defect is related to the former one of a lack of a sound conceptual basis in that the researcher dealing with a limited group like this typically is operating within a conceptual framework which is at

least as limited as the sample with which he is dealing. For example, the investigator may focus upon a rather limited set of teaching techniques which supposedly are consistent with the curriculum materials being studied in an institute. This degree of specificity is in and of itself not a problem. The difficulty is the lack of relationship between what is being studied and all of the other possible teacher strategies or styles that might be considered.

In other words, the researcher often seems to be suffering from failure to see the "big picture" and is focusing his attention upon some specific teaching acts which are of interest to him because of his involvement with a specific local endeavor rather than focusing upon the study of teaching strategies and styles which are identified as a result of study of the total framework of possible science teaching approaches. The researcher often is responding to a problem of immediate practical concern to him rather than dealing with problems which he identifies out of intensive study of the existing literature with a view of then attacking a specific problem whose solution has some hope of contributing to the overall literature.

The myopia is in many ways similar to the third weakness identified above: the failure to deal with other categories of variables which might be related to the teaching variables directly under study. Much attention has been given to the study of teaching behaviors in the last decade but too rarely does the investigator attempt to deal with learning outcome variables or other groups of variables in a manner which gives potential of relating teaching strategies to particular learner outcomes.

Among the studies contained within this section which are worthy of specific mention here is a study by Bassett (19) in which he attempted to analyze oral questioning processes of elementary school teachers teaching science and to ascertain the relationship of certain other variables to the questioning process. The questions which were asked by teachers were classified within a categorization system and tabulated. Although the cause and effect nature of the language employed in presenting the correlational findings in his conclusions must be rejected, the author's findings of a relationship between age, years of teaching experience, and academic preparation and the questioning data are of interest.

In another correlational study, Wallace (351) examined the relationship between (a) selected teacher characteristics and school environment variables as perceived by teachers and (b) the successful implementation in the teachers' classroom of a new elementary school science curriculum, i.e., Science - A Process Approach. The Purdue Teacher Opinionnaire, Stern Activities Index, and Organizational Climate Index were used as measures of independent variables. The degree of success in implementing the new science curriculum materials was assessed in accordance with the number of exercises taught by the teacher during the school year and student learning as measured by the Competency Measures contained in the curriculum materials. Stepwise multiple linear regression analysis was employed. "The only factor from the pool of

factors scores significantly related to pupil achievement as determined by the Science - A Process Approach Competency Measure was the Organizational Climate Index factor for Intellectual Climate. The full regression model composed of the twenty eight first-order combined factors from the three research instruments was shown to be a significant predictor of the number of exercises a teacher is likely to teach in a school year, but this full model was not a significant predictor of pupil achievement on the competency measures."

Disinger (84) investigated the relationships between junior high school science students' cognitive and affective characteristics and certain teacher characteristics and class characteristics. A fairly extensive number of instruments was employed in measuring the various characteristics. Correlations between the various characteristics were reported.

Based on a factor analysis of questionnaire data collected from participants in a Project Physics Summer Institute, Yegge (373) studied factors related to teachers' decision to adopt or not adopt new curriculum materials. Three clusters of factors which discriminated between the adopters and nonadopters were identified. They were descriptive of teacher's perceptions of (a) the "support" that they had from "significant others" in the school's hierarchy of decision makers, (b) the "process of adopting a new physics course" as being "important," "wise," "helpful," "professional," and "productive," and (c) their own professional characteristics.

In an interesting study conducted at the college level, Bridges and others (36) studied the outstanding characteristics of the best college teachers and worst college teachers as perceived by students, faculty members and administrators. They presented characterizations of both best and worst teachers in each of twenty four categories such as knowledge of subject, enthusiasm, research, classroom management, communication, interest in students, evaluation, and humor. The views of teachers, students, and administrators were compared and found to have an "extremely high degree of agreement" as to the perceived relative importance of the various categories. The findings of this study should provide a reasonably good empirical basis for the development of evaluation instrument with meaning for faculty, administrators, and students.

In a somewhat different kind of study, Klein (175) conducted case studies of five elementary level MAT candidates. She provided descriptive data on these five teachers and their backgrounds as well as their actions in the classroom. In addition, data from a Flanders Interaction Analysis and from the Edwards Personal Preference Schedule were employed. Common themes were identified.

Two other studies in this section are particularly interesting because of the rationale which underlies them. The first of these, Power (258), is significant because of its movement away from some of the difficulties attributed above to the studies in this section. A study was

made of the effects of teacher feedback and communication patterns in eighth grade science classes. Both teacher and pupil behavior were classified, levels of student participation determined, and measures obtained of pupils' cognitive abilities, personality, expectation of success in science, achievement motivation, sociometric status, attitude toward science, and science achievement. Multiple discriminant analysis was employed. The study is interesting both in terms of the findings and the hints that it provides of directions that might be taken in studies of teachers and teaching.

Finally, mention should be made of a study by Bashook (18) because of the potential stimulus it might provide to the researcher interested in investigating this area. Although the results are not particularly conclusive, the methodology of this exploratory study may be of interest to researchers interested in analyzing and evaluating teaching strategies.

Other studies included in this section are: (13), (31), (40), (43), (44), (56), (59), (71), (100), (164), (170), (187), (203), (209), (214), (222), (231), (242), (255), and (337).

Teacher Education

Because the studies of teaching have produced so little definitive information, as described in the previous section, the researcher who hopes to investigate teacher education must begin with an abundance of assumptions about what teacher behaviors should be sought in a preparation program. Ideally, the scholar investigating teacher education would have empirical evidence which indicates what teacher behaviors could be expected to result in particular educational outcomes among students. This is not the case, of course, so the investigator must embark upon the study of procedures for inculcating particular teacher behaviors, strategies or styles for which only sketchy empirical evidence and numerous assumptions are available to indicate their desirability. Taking all of this as a given, however, there is much to be done in the study of teacher education to determine what educational processes are useful for reaching a variety of teacher behavior goals.

In examining the studies of this section, one of the striking characteristics of the group is the relatively small number of comparative studies; this characteristic is in contrast to the elementary and secondary school science teaching instructional procedures reviewed earlier. Many researchers have simply set about studying a particular instructional process, such as micro-teaching or role playing, and examining the gains in certain desired outcomes which result. This is a serious deficiency, of course, which cannot be ignored. As described earlier, most of the comparative studies conducted in science education, as in most of education, tend to be poorly done but the solution is not to revert to the completely inadequate design which Campbell and Stanley (45) have called the "one-shot case study." The answer is to conduct comparative studies of quality in which the common critical failures of conception and design are eliminated. Without well done comparative studies conducted

in abundance in a variety of situations, there is little hope that in future years we will have an understanding of what teacher education strategies are productive for what purposes, under what circumstances, and for what kinds of teachers.

Much of what was stated earlier about the necessary features of comparative studies applies here as well. A researcher should not bother to do such a comparative study unless the treatment is very carefully described, or better yet carefully delineated and planned in advance in addition to being described, so that a specific teacher education technique is being compared with another one of equally careful description and/or specification. There is no hope for making careful comparisons of what we have not even described.

The need to consider a variety of possible outcomes of a given teacher education approach should not be overlooked. As with comparative studies of elementary and secondary school science instructional procedures, the person investigating teacher education approaches must consider the variety of cognitive and affective outcomes which may result. In addition, of course, provision must be made for searching out possible interactions between the treatment and characteristics of the teacher trainees in terms of this variety of dependent variables.

For the person who wants to evaluate the impact of a particular in-service education program, summer institute, or total preservice teacher education, the investigator is well advised to be sure he has an up-to-date understanding of the methodology of evaluation. As noted earlier, the methodology of evaluation has changed substantially, in fact largely has originated, within the last decade. Although the evaluator should attempt to conduct comparative studies as part of his total evaluation wherever possible, there is a wide variety of other approaches that can be taken within the formative and summative evaluation framework. Under many circumstances an attempt to produce generalizable knowledge for publication is unusually difficult. The evaluator should set about aiding the decision making process and improving the program through sound evaluation practices rather than contributing another unproductive "pseudo-research" study to the published literature.

A study by Koran (180) is illustrative of much of what <u>should</u> be found in comparative studies of different teacher education strategies. He compared the effects of two different models, a written model and a film-mediated model, on the acquisition of a specific science teaching skill by prospective elementary teachers. Among the noteworthy features of this study are the following: (a) the two techniques for presenting the skill to be learned were carefully developed and then described for the reader, (b) the particular skill being taught was fully described, (c) the two models compared and the specific behavior taught were selected on the basis of past research with the resulting possibility of adding to knowledge in the field rather than adding just another unnecessary study, and (d) consideration was given to the individual student response to the two models even though the study was not specifically

designed to compare the effectiveness of the two approaches in terms of variations in student characteristics (the study could have been improved by the addition of some teacher characteristic(s) as an independent variable). This study provides an indication of the direction that needs to be taken if comparative studies are to be productive.

Researchers will need to consider as independent variables carefully defined treatments, skills being taught and characteristics of the teacher education student as well as the potential interactions among them. No one study of this nature will answer the majority of our questions, but a large number of studies of this type, carefully designed to build on previously completed studies, have the potential of providing the basis for inductively arriving at some important generalizations about teacher education.

Hughes (149) compared three variations of a role playing technique and a control group, in terms of their impact on elementary teacher trainees' attitude toward science. As with the Koran study, no teacher characteristic is included as an independent variable but the study has considerably more potential than most for ultimately aiding in gaining a better understanding of teacher education. In another well designed study, Illingworth (152) compared three versions of feedback in a micro-teaching sequence designed to teach effective question asking. The three forms of feedback were supervisor feedback, peer feedback, and a combination form, a fourth group served as a control. Criterion variables were the number of questions asked, the number of higher order questions asked, and a rating of questioning skill. No significant differences were found between the treatment groups in terms of the number of questions or number of higher order questions asked but significant differences were found in terms of questioning skill for the two groups that included supervisor-feedback.

In a study which lacks some of the definitiveness of those referred to above, Shutte (289) compared a micro-teaching technique and a traditional observation discussion technique for science teacher preparation. Flanders Interaction Analysis was used as a measure of change in teaching skill. The comparison of the two versions of student teacher supervision indicated some variation in the patterns of verbal interaction of the two groups but overall, as measured by I/D ratios, no significant difference was found between the two supervision methods.

Two studies conducted of university training programs or portions of training programs illustrate current investigations of this nature. One of these, conducted by Christiansen (54), was basically the collection of information on several characteristics of the preservice elementary teachers in an university program followed by a search for correlations among these variables. It suffered from many of the weaknesses of such "shotgun" correlation studies as discussed previously. Although it produced interesting little tidbits, such as preservice teachers' attitude toward science content courses was less positive than towards science methods courses, not much results from the study which has the potential of aiding science educators in improving teacher education programs.

In the other study, Brewington (35) compared different versions of a university science teacher education program. A wide variety of self report and observation checklists were employed in collecting data. Correlation and regression analysis, along with analysis of variance and covariance, were employed in this well designed study. The results of the study indicated differences between the two versions of the program in terms of teacher attitude and teaching methods employed.

A quite different approach to the study of teacher education is illustrated by a study conducted by Kendzior (171). It is one of but a few studies in which case study techniques have been employed to describe in depth what happens to a few students during their teacher education program. A wide variety of information was acquired via audio and video recordings, questionnaires, interviews and observations of the investigator. Intensive analysis was conducted of the activities and perceptions of two subjects. The results of this investigation were cast into perceptual frameworks which represent "the processes and the products of beginning teachers' attempts to bridge the gap between theory and practice."

Finally, brief mention should be made of yet another type of study that falls within the teacher education category. These studies are surveys of teacher education programs or the demand for teachers on the part of employers as illustrated by a study conducted by Strassenburg (322). A survey was made of physics department chairmen in community colleges of one state to obtain information on degrees held and coursework backgrounds of current staff members and the chairmen's views of the acceptability of the Doctor of Arts degree.

Other studies included in this section are: (17), (22), (42), (52), (67), (75), (78), (80), (104), (106), (111), (112), (113), (116), (133), (138), (139), (154), (191), (192), (197), (211), (236), (237), (241), (244), (249), (251), (261), (266), (267), (279), (312), (345), (363), and (370).

METHODOLOGICAL STUDIES

Although the title of this section indicates the inclusion of a wide variety of studies directed toward advancing the methodology of conducting research in science education, the studies contained within this section are focused almost exclusively upon instrument development. The instruments developed through the studies described below may be of interest to the researcher in need of a particular type of data gathering device. Since the review of studies given below obviously is not a comprehensive reviewing of all of the available instruments of a given type and since decisions concerning the selection of instruments will require the examination of the instrument and other supporting documentation, this section should be viewed as a source for identifying instruments which should be investigated and not as a basis for selecting an instrument to be used.

Among the instruments within the affective domain is one developed by Steiner (318) to ascertain student's attitudes toward societal issues related to science and technology, such as population, environmental and pollution issues. A large number of Likert-type items were constructed, administered, and subjected to a factor analysis. Seven factors were identified and items from them used in constructing a sixty item Inventory of Societal Issues (ISI). Total scale reliability for ISI is reported to be .77.

Huston (151) developed an instrument to assess the value orientations of high school students or teachers to the "theoretical, humanistic and technological aspects of chemistry." Reliability coefficients for the three subscales of the instrument range from .72 to .90. Content validity was said to be established by categorization of the instrument statements by a panel of experts. The instrument was administered to Theology students and Engineering students and the data used in support of the construct validity of the instrument.

Richardson (271) developed an instrument for measuring sixth to ninth graders' interests in science and their scientific curiosity. Test-retest reliability of the total instrument was .72. A factor analysis of the responses of a group of students identified nine factors. Of the 110 items on the inventory, 64 were identified as being useful for measuring the identified nine factors.

Among the cognitive instruments was one developed by Sack (281) to test the concepts of shadows and light of second graders. The intent was to develop an instrument which minimized reading and could be administered by the person without special training. Once assembled, the instrument was tested with small groups and individual pupils. Individual children were interviewed individually to ascertain the reasons for their selection of all alternatives. The test's reliability coefficient was reported to be .69 and the test correlates with mental age and reading by values of .267 and .279 respectively.

Fyfee (105) developed an instrument to measure two processes of the Science - A Process Approach curriculum materials: Formulating Hypothesis and Defining Operationally. Individual competency measures from these curriculum materials were used with individual students simultaneously with administration of the developed instrument as a basis for establishing validity.

A measure of problem solving performance was developed by Norton (238) for use with fourth, fifth, and sixth graders particularly. The test, labeled the TAB Science Puzzler, utilizes the TAB format and was designed to measure total problem solving skill and ability to perform on five subtests. Intraform reliabilities of parallel forms of the instrument range between .73 and .80.

A third category of instruments developed deals with the study of teacher and student actions in the classroom. In one of these, Berger (26) developed an instrument to identify behaviors which teachers predict they will use while teaching elementary school science. The instrument is titled the Predicted Role Measure (PRM) and consists of a motion picture film and a paper and pencil instrument on which teachers mark their response. Likert-type items are used for teacher response after viewing each of the nine scenes in the film. Responses are used to yield role scores on three dimensions labeled as The Teacher Emphasis Role, The Student-Teacher Cooperation Role, and The Student Emphasis Role. The rankings of judges were used to determine the relationship of the items to these three roles. The instrument was administered to 184 elementary school teachers with varied degrees of instruction in and experience with the use of SCIS materials and who are identified as being "book-centered" or "activity-centered." The instrument could differentiate significantly between several of these various groups of teachers.

Johnson (160) developed a communications model of Classroom Interaction and three uni-dimensional instruments for translating the communications observed and recorded in a classroom. The three instruments were designed to reflect the cognitive, affective, and communication modes of the classroom.

Knamiller (176) conducted a study to develop "observational frameworks" for viewing children's responses to the classroom environment including science materials and events, other students, and the teacher. Largely through a case study approach, four observational frameworks were evolved. These frameworks were labeled as The Category of Possibility, The Teacher Puzzler, The Apprentice, and The Improvisation.

Other studies included within this section are: (21), (46), (65), (125), (130), (181), (213), (217), (228), (240), (250), (283), and (349).

MISCELLANEOUS TOPICS

This section contains a rather diverse group of studies which do not fit clearly under any of the categories examined above. In terms of methodology employed, most of the studies are surveys with a fair number of content analysis studies and a few scattered case studies, historical studies, and philosophical treatises. The major weakness of the studies in this section is the trivial nature of many of the questions addressed. This is particularly true of the large number of surveys contained herein; few of them yielded information that is of much utility or widespread generalizability.

A particular disappointment to this reviewer is that the few historical and philosophical studies in this section constitute nearly all of the studies of this type within the entire review. To a large extent, they do not live up to the hope that one might have for the insights that could be gained through well-done historical or philosophical inquiry.

As with the surveys contained herein, the major problem of these historical and philosophical studies is the insignificance of the questions addressed. Possibly because of their common background in the natural sciences, science educators seem to focus on empirical studies to the almost total exclusion of historical and philosophical inquiry. Hopefully, some scholars will emerge from the science education community who will employ historical and philosophical inquiry to examine some of the more profound questions in the field.

Of the studies contained in this section, several content analyses of printed materials appear worthy of specific mention. LaDuca (184) analyzed the teachers' editions of curriculum materials produced by major curriculum development projects to identify the teaching models espoused and employed therein. The results of the content analysis were interpreted as dividing the materials into three groups in terms of the distributions of teacher behaviors promoted. They were labeled as the Process Management Model, Lecture/Discussion Model and the Inquiry Discussion Model. Different materials prepared by the same curriculum development project were said to contain the same distributions of teacher behavior.

In another study, Walker (350) recorded the deliberations of three different curriculum development projects staffs as they planned initial versions of curriculum plans and materials. A content analysis system was applied to the transcribed discourse. The system employed enabled judges to identify episodes, smaller units identified as deliberative moves, and arguments. From the findings of this analysis, the author developed a model of the curriculum development process and explored its implications for educational research, practice and theory.

Greenlaw (120) examined children's science fiction to determine the extent to which it reflected adult concern with technological considerations and technology's impact on human values. The study included thematic analysis with the identification of six theme categories, and a second content analysis which identified three value categories (individualism, privacy, and "others") and three technological topics (nuclear power, automation, and massification of society). "It was concluded that children's science fiction was not primarily escape literature. It contained significant themes and values that are a commentary on society in general and technology's impact on human values in specific."

Some hundred journal articles dealing with science, technology, and public policy were examined by Mierzwa (218) to identify the broad range of viewpoints in this field and the interactions among science, technology, and society. The author reports that his findings lead him to conclude that there is a need to include more consideration of the interactions among science, technology, and society in the science curriculum of the schools.

In yet another study employing content analysis, Stambler (314) examined 43 elementary physics college textbooks which were published between 1910 and 1966 to determine the extent to which a transition from

classical Newtonian concepts to modern concepts of physics has occurred. A major conclusion of the investigator is that the authors of these books "have not kept pace with the newer knowledge and changing socio-scientific conditions."

In an unusual study which is quite different from the content analysis studies referred to above, Kass (166) employed multidimensional scaling techniques to summarize the structure of student's perceived relations among specified mechanics concepts on the basis of judgments of the concept's similarity with respect to difficulty. A motion dimension and a vector dimension were interpreted as generalized continua of the concepts. Such multidimension representations are judged by the author to be useful configurations for studying the effects of various variables.

Of the many surveys included in this section, two which may be of relatively greater interest and significance are discussed here. One of these surveys was conducted by Chin (53) to obtain information about conditions, policies, practices, and procedures which affect science education in public secondary schools of the Far West and Great Lakes regions. The information reported was obtained as part of a large national survey. Mail questionnaires were administered to principals and teachers who had been randomly selected in a multi-stage sampling process. The response rates for the Principal's Questionnaire and Science Teacher Questionnaire were 44.7% and 45.6% respectively. A large amount of descriptive information was collected and reported relative to such matters as organization of the school day, budgets, policies for grouping of students, curriculum materials employed, characteristics of teachers, and learning activities employed.

In another survey study, Roth (278) undertook the development of a taxonomy of objectives with potential utility in planning instructional programs related to environmental management. The conclusions were based on data collected from experts in forty professional areas and from twelve different ecological regions of the country.

Other studies included in this section are the following: (6), (7), (9), (34), (48), (62), (66), (68), (79), (85), (86), (89), (102), (103), (126), (127), (132), (162), (169), (177), (186), (198), (220), (221), (235), (245), (256), (257), (273), (277), (285), (290), (291), (307), (309), (324), (331), and (332).

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